

sure of U.S. patent application Ser. No. 09/860,721 to teach the rudimentary concepts of a jet disturber, the present invention should in no way be viewed as limited by the disclosure of U.S. patent application Ser. No. 09/860,721. For example, while U.S. patent application Ser. No. 09/860,721 describes the jet disturber as preferably being used in conjunction with a multi-capillary inlet, for purposes of this disclosure, such is not necessarily required.

One aspect by which the present invention expands and extends the utility of the jet disturber is through the use of voltages applied to the jet disturber. In contrast to the enhanced ion conductance generally associated with the use of a jet disturber as taught in U.S. patent application Ser. No. 09/860,721, the use of an applied voltage can have the opposite effect. For example, a suitable dc voltage applied to the jet disturber can attract ions passing through the primary set of elements, thereby preventing them from passing. Alternatively, another suitable dc voltage applied to the jet disturber can repel ions passing through the primary set of elements, also preventing them from passing. In between these two extremes, the passage of ions can thus be easily controlled by the application of voltage to the jet disturber. As will be recognized by those having skill in the art, the voltage applied to the jet disturber can be easily controlled with a suitable power supply, and may further be rapidly changed as desired by the user. Thus, the present invention is further enhanced by the use of jet disturbers connected to a power supply in one or more of the primary sets of elements, as this allows the user to readily adjust the passage of ions through that primary set of elements.

The present invention is thus a multi-source ion funnel for introducing ions from a region at relatively high pressures to a region at relatively low pressures having at least two sets of primary elements having apertures, each set of elements having a receiving end and an emitting end, the first sets of elements configured to receive a ions from at least two separate ion sources at the receiving ends, and a secondary set of elements having elements having a receiving end and an emitting end, the secondary set of elements configured to receive said ions from the emitting end of said primary sets of elements. The multi-source ion funnel may further utilize at least one jet disturber positioned within the interior of at least one of said sets of primary elements, and may include a means for providing a voltage to the jet disturber.

As utilized in a mass spectrometer, the present invention includes at least two electrospray ion sources, at least two capillary inlets, and a multi-source ion funnel, wherein each of the electrospray ion sources is configured to direct ions generated by the electrospray sources into and through each of the capillary inlets, and the capillary inlets are further configured to direct the ions into the receiving end of the sets of primary elements.

The present invention is thus also a method for introducing ions generated in a region of relatively high pressure into a region of relatively low pressure by providing at least two electrospray ion sources, providing at least two capillary inlets configured to direct ions generated by the electrospray sources into and through each of the capillary inlets, providing at least two sets of primary elements having apertures, each set of elements having a receiving end and an emitting end, the primary sets of elements configured to receive a ions from the capillary inlets at the receiving ends, and providing a secondary set of elements having apertures having a receiving end and an emitting end, the secondary set of elements configured to receive said ions from the emitting end of the primary sets of elements and emit said ions from said emitting end of the secondary set of elements.

The method may further include the step of providing at least one jet disturber positioned within at least one of the sets of primary elements, providing a voltage, such as a dc voltage, in the jet disturber, thereby adjusting the transmission of ions through at least one of the sets of primary elements. The step of adjusting the transmission of ions may prevent the transmission of ions, and the applied voltage may be applied intermittently, for example as a square wave form, thereby providing intermittent disruption of the ions.

A preferred embodiment of the present invention utilizes a luti-source ion funnel in an ESI-MS instrument. A jet disturber is provided within each of two sets of primary elements to control the transmission of calibrant and analyte ions. The transmission of calibrant and analyte ions may be controlled in either a dynamic or in a static mode. Utilized in this manner, the present invention provides a particularly useful method for introducing calibrant ions and analyte ions into a mass spectrometer. As the voltage is alternated between the jet disturbers, the disruption of the transmission of calibrant ions and analyte ions is likewise alternating through the sets of primary elements.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

FIG. 1 is a schematic drawing showing the basic configuration of multi-source ion funnel of the present invention.

FIG. 2 is a schematic drawing showing the basic configuration of multi-source ion funnel of the present invention when utilizing multipoles in the sets of primary elements.

FIG. 3. Shows a dual-channel API interface on the Agilent MSD1100 single quadrupole mass spectrometer with the (a) dual heated capillaries and (b) dual-channel ion funnel of different diameters with a jet disturber installed in the smaller diameter channel.

FIG. 4 shows a full scan mass spectrum at (a) jet disturber voltage of 165 V for optimum ion transmission, (b) jet disturber voltage of 110 V for maximum suppression of ion transmission, and (c) ion transmission modulation for reserpine ions at m/z 609, and at different jet disturber DC bias voltages. Agilent ESI tuning mix was used for the main ion funnel channel electrospray, and reserpine solution was used for the jet disturber channel electrospray. Ion funnel voltage settings: DC+, 201.9 V; DC-, 36.4 V; RF, 70 V_{p-p}, 500 kHz; DC_{cap}, 218.8 V; temperature, 150° C.; ESI infusion rate, 2 μ L/min.

FIG. 5. is a comparison of sensitivity for different m/z ions at different jet disturber DC voltages: (a) 165 and (b) 115 V using the same experimental conditions as specified in FIG. 6.

FIG. 6 is a graph showing ion transmission through the jet disturber channel at different DC bias voltages for different m/z ions from Agilent ESI tuning mix. The ion funnel voltage settings were: DC+, 201.5 V; DC-, 35 V; RF, 70 V_{p-p}, 500 kHz; DC_{cap}, 218.9 V. Temperature, 150° C.; ESI Analyte ion funnel channel, reserpine (1 ng/ μ L), Calibrant jet disrupter) ion funnel channel, Agilent ESI tuning mix; infusion rate, 2 μ L/min.

FIG. 7 is a graph showing the efficiency of dynamic ion transmission modulation through the jet disturber ion funnel channel: AC voltage on the jet disrupter, 0.2 Hz square waveform with voltage alternation of 100–156 V; duty cycle, 95% (250 ms high and 4.75 slow).

FIG. 8 is a graph showing ion transmission vs the jet disturber DC offset. Simulations for pressure 2 Torr, m/z = 1000 Da, ion with cross section 3E-14 cm², axial gas flow